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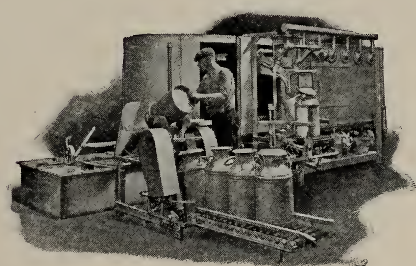

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THE CONTINUOUS CAN WASHER FOR DAIRY PLANTS

A. W. FARRALL[1]

Milk, as scientists have long recognized, must be handled in containers which are clean and reasonably free from bacteria, if it is to be of highest quality when delivered to the consumer. Many experiments[2] have shown that milk may be badly contaminated by contact with unclean surfaces. The cleanliness of the milk can is therefore of great importance: it is usually the first container and holds the milk longer, perhaps, than any other single piece of equipment. Contamination at this stage of the handling of milk is difficult to overcome. Much thought has been given to the cleaning and sterilizing of milk cans, and special machinery has been developed for performing this important function. Many plant operators apparently lack fundamental knowledge and operating data regarding such machinery, and fail to appreciate the importance of properly caring for and operating the can washer. Because the problem is fundamental to the improvement in quality of dairy products, and to more efficient use of labor in the dairy plant, a study of its more important phases has seemed desirable. The Dairy Industry and Agricultural Engineering divisions of the University of California. in cooperation, have therefore conducted an investigation of the following points:

Types of washers in use.
The washing process.
The steaming process.
The drying process.
Power requirements of various types of washers.
Factors affecting the successful use of a continuous washer.
Proper care of washers.

A number of tests were first conducted on washers in actual use in creameries, in order to determine such factors as power requirements and general operating characteristics. This investigation was followed by a detailed study of a machine in the laboratory of the Dairy Industry Division, University of California. A special supplementary study was also made of the steaming of milk cans over jets.

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[1] Assistant Professor of Agricultural Engineering and Assistant Agricultural Engineer in the Experiment Station. Resigned December 31, 1928.

[2] See Ayers, S. H. Four essential factors in producing milk of low bacterial count. U. S. Dept. Agr. Dept. Bul. 642:1–8. 1918.

TYPES OF WASHERS

The principal types of continuous can washers in use might be designated as to (*a*) form, (*b*) type of circulation system, and (*c*) type of jets.

Form.—Can washers are usually of the rotary or straight-away types, although some of the newer designs are a combination of the two, with a dividing wall between the washing and drying compartments.

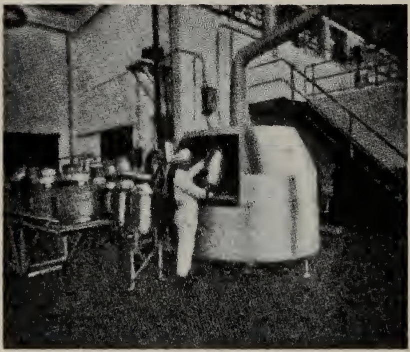

Fig. 1.—A common type of rotary can washer. One man places the cans in the machine and removes them as they come out. This type of machine does not lend itself readily to the large, continuous system in which cans are automatically fed into the machine and removed in the same manner. It finds its greatest use in the small and medium-sized plants.

The rotary can washer, (fig. 1) which is simple in construction, usually carries the cans on a large rotating table or carrier. It will ordinarily handle battered, out-of-shape cans without trouble due to their falling over and stopping the machine. The smaller sizes are compact and easy for one man to load and unload, but the tanks are sometimes rather inaccessible for cleaning.

The straight-away type (fig. 2), usually carries the cans through the washer by means of a rachet drive, which at regular intervals shoves them ahead from one position to the next. Difficulty is sometimes experienced because of misshapen cans falling over and clogging the machine. This type has certain advantages: it is usually accessible for cleaning, and, it fits into a continuous transfer system which sets the cans out on a roller conveyor and replaces the lids, thereby saving labor and time in operation.

The combination rotary and straight-away is really a double straight-away type which carries the cans away on one side and back

on the other. This arrangement has one great advantage over either of the other types mentioned, in that it places a positive protecting wall through the center between the washing and drying compartments, thus preventing water and solutions from splashing on or into the dry cans.

Circulating Systems.—Can washers may be classified as those *using* motor-driven centrifugal pumps, steam-driven pumps, and the so-called 'steam-gun' (fig. 3). Mortor-driven centrifugal pumps are widely used for circulating washing and rinsing water, because of their simplicity, dependability, and economy of operation. They have the disadvantages of being subject to clogging if the solution is not kept clean, and of being incapable of supplying high pressures. The pressures used range from 20 pounds per square inch upwards.

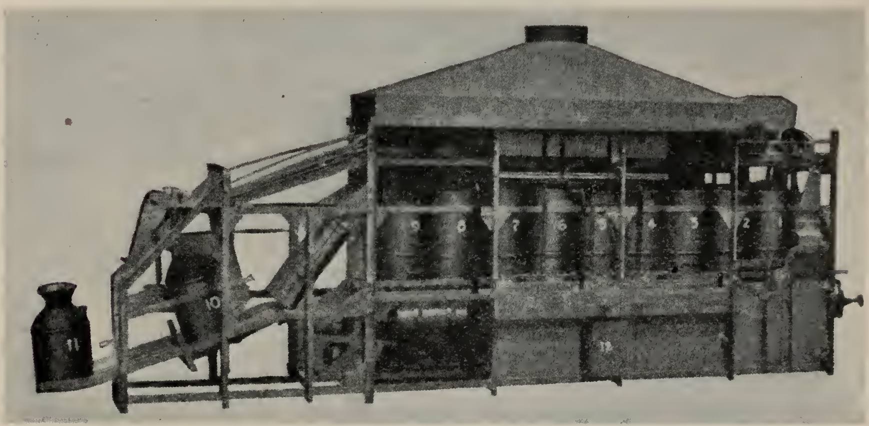

Fig. 2.—A straight-away type of can washer, which can be fitted with automatic loading and unloading devices and is easily accessible for inspection and repair.

The steam-pump-driven washer uses a duplex steam pump for circulation of the solution, and offers the advantage of using exhaust steam for heating this solution. One very important point is, however, that unless a very efficient oil separator is used, there will be trouble with an oily film collecting on the cans and in the washer. This type of pump usually furnishes a pressure of 60 to 90 pounds per square inch at the jets. The upkeep of such a system is considerable, because of vibration and the necessity of repacking and keeping the pump properly adjusted. This type of washer consumes a large volume of steam.

The steam-gun type of circulating system uses a steam jet on the principle of the ejector to force the solution up into the cans. It has

the advantage of simplicity. The principal difficulty is that the steam-gun may 'lime up' at the nozzle and thus reduce the capacity. However, this is not a serious disadvantage, for the gun can be easily cleaned.

Jets.—Jets may be classified as intermittent or continuous; as stationary or rising, (or in the case of a combination of these) as rising-intermittent.

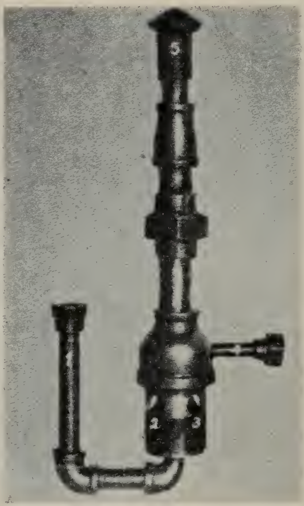

Fig. 3.—A 'steam-gun' which is used to force washing solution into the cans.

The tendency seems to be to make use of very few continuous jets except for air and washing solutions. Most washers of the late type use intermittent flow for all water and live-steam jets, in order to effect economy of operation when cans are not being treated. The jet is on for only a few seconds while the can is actually in place, or as in some intermittent types, for a regular number of seconds during the minute. The latter does not save so much steam as the former, but may be preferable from a mechanical standpoint. The former type makes a considerable saving in a plant where the cans are washed in intermittent batches.

Rising jets, or what amounts to about the same thing (rising deflector jets) are used in some washers to make the jet strike all parts of the can directly. They are correct in principle, and should prove to be satisfactory when the mechanics involved is thoroughly worked out so that no troublesome mechanism is used.

PRINCIPLES OF OPERATION

Authorities are not in entire agreement upon the proper treatment of milk cans in a washer; but they unite in recommending the following processes:

1. Drain out any milk or cream which remains.
2. Rinse thorough with clean, cool water to carry out most of the milk film which may remain in the can.
3. Use some method such as steam-soak or warm solution treatment to dislodge any material which may adhere to the can.
4. Rinse with clean, hot sterile water to remove all traces of washing solution.
5. Sterilize thoroughly with wet steam.
6. Sterilize with dry or superheated steam.
7. Treat with hot air blast to remove the remaining moisture.
8. Treat with a cold air blast to remove the hot air, which causes condensation upon cooling.

Some changes in the above cycle are made to meet special conditions, as in the case of cans containing frozen milk, when it is necessary to use a thawing or heating device near the first of the cycle. In carrying out the cycle of operation, a washer may make use of two or more successive similar treatments, as is the case when two hot-air jets are used for drying the can.

The ideal washer should turn out a can which is clean, dry (i.e., without visible free moisture), and practically sterile. The dryness is perhaps more important than complete sterilization, for in actual practice it is almost impossible to obtain the complete destruction of bacteria, and, if the can is dry, these remaining bacteria do not multiply. If the can remains wet, however, it affords a very favorable place for bacteria.

It is advisable to give the outside and the lids the same treatment that is given to the inner surfaces of the cans.

Draining of the can is usually accomplished by allowing it, before it is rinsed, to pass in an inverted position over a drip pan, which collects the milk and directs it into a suitable receiver.

Rinsing is a simple matter and calls for a good volume of water of moderate temperature, which will come in contact with all parts of the can. A single jet is often used successfully for this purpose. The temperature is normally 60° to 70° Fahrenheit. Care should be taken that the water pressure supplied is sufficient to throw a good stream with considerable force up into the can. Usually about 20 pounds pressure is required.

THE WASHING PROCESS

Washing is one of the most important functions of the machine, as well as one of the most troublesome. The removal of all foreign material is not easily accomplished, on account of the tendency for any dried film of milk or cream to adhere tightly to the surface of the metal. Cracks or other rough places in the interior of the can are difficult to clean. The shape of the can is also a factor, because it is not easy to bring the washing medium directly to some parts, especially near the throat. The methods used involve a soaking action, augmented by a forced rinsing with a high-pressure jet of washing solution. No mechanical brushing device has as yet proved successful in a continuous can washer, although such a device would have several advantages.

Much thought and effort have been expended in the attempt to develop a suitable *jet* which would accomplish the desired result. Rising jets or rising deflector jets are expected to solve the problem by causing the jet to traverse the inside of the can and strike it directly on all parts of the surface. There is little doubt that this principle is good. The stationary jet has the advantage of simplicity and ease of upkeep, but it does not give the thorough treatment of a rising jet. Good results have been obtained with it, however, and its simplicity is a big factor in its successful use.

TABLE 1

Effect of Cleaning Washer Upon Bacteria Content of Cans Washed

Can No.	Bacterial count on cans passed through washer, Bacteria per cc*	
	Before cleaning washer	After cleaning washer
1	More than 1,000,000	8
2	More than 1,000,000	6
3	More than 1,000,000	30
Average	More than 1,000,000	14

* Bacterial count obtained by plating 1 cc of 400 cc of sterile water used for rinsing the can.

Note.—Can washer had been operated for one month without cleaning of tanks or jets except for rinsing. Some of the jets were completely stopped up. Strainer was also badly stopped up. Cans came through wet and unsatisfactory. Cleaning consisted of thorough washing of all tanks, disassembly of all jets, and removal of deposit from strainers.

A large volume of water is desirable for the washing operation. Some washers circulate as much as 10 to 12 gallons per can per jet. Jets have an important place in the washing process, and their stoppage by the collection of foreign material in the openings is one of the serious difficulties encountered in can washers. Table 1 shows how this stoppage affects the quality of work done by the washer. It will be noted that the bacterial count taken on cans which had

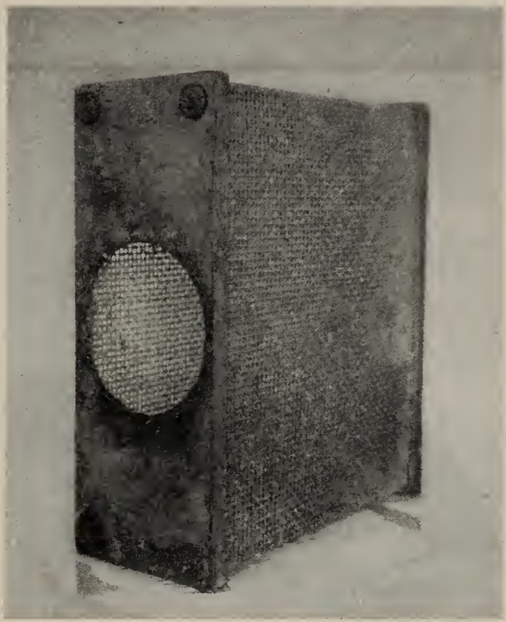

Fig. 4.—A strainer located in the bottom of the tank over the suction inlet to the pump for the purpose of keeping foreign material out of the jets. Note that a deposit of foreign material has formed on the surface of this strainer, thereby increasing the resistance to flow through it.

passed through the washer when it was dirty and the jets partially stopped up, was over 1,000,000, while the same washer after a thorough cleaning gave cans with an average of only 14 bacteria per cc in the rinse used. In addition to the marked reduction in bacterial count, there was a great improvement in the appearance of the can. The washer in question had operated one month without thorough cleaning. Stoppage was due to a collection of strings, tags, caked washing powder, and hair. In view of the above results, it seems desirable to clean out all jets with a wire every day. Jets with one or two large openings are not so easily stopped up and are more easily cleaned than those that have many fine holes.

The *strainer* used to prevent foreign material from being drawn into the pump also needs occasional cleaning, for it has a tendency to collect a heavy deposit, making the flow of solution through it so difficult that the volume at the jets will be reduced. Figure 4 shows a typical strainer so nearly clogged by deposit that the solution flows through it with difficulty.

TABLE 2

DATA SHOWING THE TEMPERATURE OF MILK CANS AT DIFFERENT STAGES OF THEIR TRAVEL THROUGH A CONTINUOUS CAN WASHER

Position of can	Treatment of can at position indicated	Temperature of can after treatment indicated	Treatment of can in previous position
Entering	None	63	Exposed to atmosphere.
After first rinse	Cold water jet 67° F	65	None.
After first wash	Washing solution 163° F	140	Cold water jet 67° F.
After second wash	Washing solution 163° F	164	Washing solution 163° F.
After sterile wash	Sterile rinse 196° F	180	Washing solution 164° F.
After wet steam	Wet steam 212° F	184	Sterile water rinse 196° F.
After dry steam	Dry steam 70 pounds pressure	183	Wet steam 212° F.
After air drier (2nd nozzles)	Dry hot air 226° F	180	Dry steam 70 lbs. pressure.

NOTE.—Can temperatures were measured by means of a maximum-reading mercury thermometer inserted in a small protected pocket soldered to the side of the can.

The *temperatures of solutions* are of importance: if they are too low, the solvent power of the solution is not sufficient to dissolve the material adhering to the surface of the can; and if they are too high, there may be a deposit left on the cans. It has been found that the washing solution containing washing powder works satisfactorily at temperatures of 150–160° F. The sterile rinse, if used at a temperature of 170–190° F, is usually satisfactory, for it contains practically no solids, and the cans are clean before coming in contact with this treatment. The high temperature assists greatly in increasing the effectiveness of steaming and drying, by preheating the can. A comparison of the data in table 2 shows that the can temperature follows closely the changes in temperature of the solution. This table shows the average temperatures of the can metal, as measured by a maximum reading mercury thermometer fastened into a pocket on the side of the can. The washing solution was 163° F, and the can temperature after treatment in the first jet was 140° F; after passing the second jet, it had reached 164° F, a point slightly higher than the temperature of the jet. This increase in temperature was no doubt

due to the splash against the can of some of the sterile wash at 196° F. After passing the sterile rinse at 196° F, the can temperature was 180° F.

The importance of maintaining proper solution temperatures is further emphasized by the fact that the hotter the cans are when they leave the solution jets, the less heat is required for steaming and drying.

THE STEAMING PROCESS

Steaming of cans usually follows the washing and sterile rinse treatments. In many washers, a wet steam treatment is applied first and followed by an application of dry steam. The wet steam heats the can quickly and efficiently, as will be shown later, while the dry steam leaves the can with the minimum amount of moisture to be removed by the drying apparatus, and at the same time aids the sterilizing process.

The object of the steaming process is two-fold, the first being to sterilize, and the second to raise the temperature of the can so that it can be easily and quickly dried by a jet of hot air. In the continuous washer, the time allotted for each process is necessarily short, and therefore all treatments *must be so coordinated that they assist each other.* Thus, if the washing treatment leaves the can hot at the time it enters the steaming compartment, the steaming will be more effective; in the same manner, if the steaming process leaves the minimum amount of water in the can, the drying process is materially hastened.

Properties of Steam.—In order to understand the application of steam to the problem, one may well consider some of the properties of steam which affect its use for this purpose. These are temperature, heat content, and moisture content.

Steam may be either wet, dry-saturated, or superheated. *Wet steam* contains free moisture: for example, steam which has 4 per cent moisture contains free water to the extent of 4 per cent by weight.

Dry-saturated steam contains just enough heat to change all of its particles into vapor. If it lost any heat, moisture would condense. It always has a certain temperature for a given pressure.

Superheated steam is dry, and contains more than enough heat to change all its particles into steam. It can lose some heat without condensing, and has a higher temperature than saturated steam at the same pressure.

Temperature of saturated steam increases with pressure, and vice versa, as will be evident from figure 5, which shows the pressure-

temperature relationship for saturated steam. Steam at atmospheric pressure has a temperature of 212° F, while at 100 pounds gauge pressure it would be 337.9° F.

Saturated and wet steam may be the same temperature at a given pressure, as shown in table 3, but superheated steam is higher in temperature. Thus at 100 pounds gauge pressure, the temperature of saturated and wet steam is 337.9° F, while for superheated steam containing 100° F of superheat, the temperature would be 437.9° F. It follows that low-pressure wet or saturated steam is perhaps just as good as superheated steam where only relatively low temperatures are required, but that for high temperature work, higher pressures or superheating must be used.

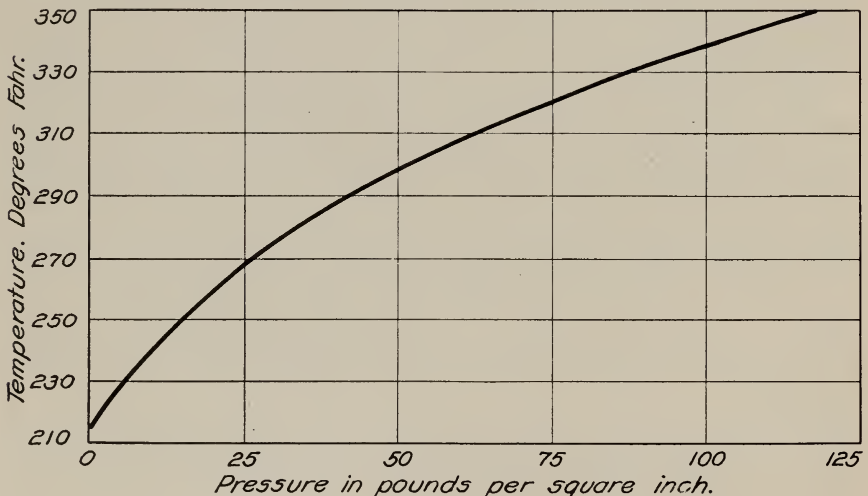

Fig. 5.—Temperature—pressure diagram for saturated steam, which shows the temperature between zero and 100 pounds gauge pressure. Note that the temperature increases with pressure. Plotted from Marks and Davis steam tables.

TABLE 3

THE RELATIONSHIP OF QUALITY OF STEAM TO ITS TEMPERATURE AND TOTAL HEAT*

Kind of steam	Temperature at 100 pounds gauge pressure, degrees Fahrenheit	Total heat in B.t.u. per pound at 100 pounds gauge pressure
10 per cent moisture	337.9	1,101.7
Dry saturated	337.9	1,188.8
Superheated 100° F	437.9	1,243.1
Superheated 200° F	537.9	1,293.0

* Courtesy Wheeler Condensing & Engineering Company.

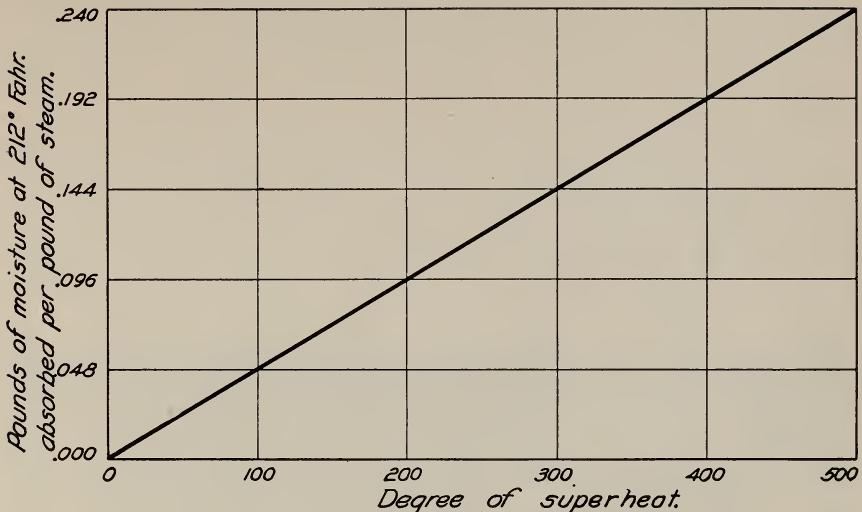

Fig. 6.—The amount of moisture, in pounds, which may be absorbed by one pound of superheated steam at atmospheric pressure, at various degrees of superheat. Data calculated from Marks and Davis steam tables.

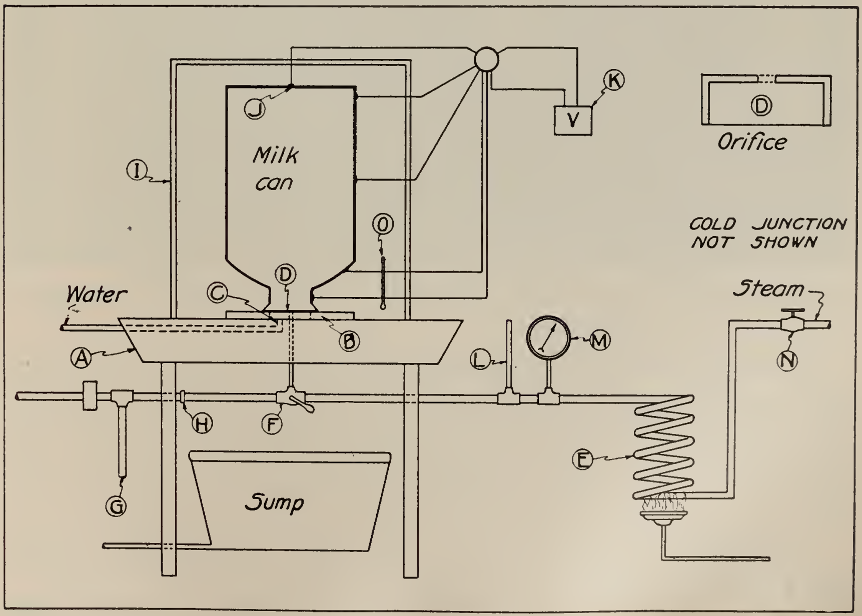

Fig. 7.—Diagram showing construction of the apparatus used for testing rate of heating of milk cans over a steam jet.

In the matter of *heat content,* wet steam, dry saturated steam, and superheated steam contain progressively greater amounts of heat per pound (by weight), as shown also by table 3, which gives the 'total heat' of steam of various qualities at 100 pounds gauge pressure.

Moisture in steam is of great practical significance: as has been mentioned previously in connection with drying of cans, *wet* steam contains moisture originally and, if used for the final steaming, will leave the can very wet, while dry steam leaves a much smaller amount; in fact, superheated steam has the power to absorb a small amount of moisture, sufficient to bring itself to the saturated condition. Figure 6 shows that the moisture-absorbing power of superheated steam at atmospheric pressure is 0.24 pound per pound of steam at 500° F superheat.

Heating of Milk Cans Over Steam Jets.—In order to study the effect of different factors on the heating of cans when steamed over jets, apparatus was built as shown in figures 7 and 8. The essential features were as follows: A table, *A,* and an adjustable frame, *B,* to support the can and other parts; a water jet, *C,* which could be turned on and off to cool the can when desired; a steam jet, *D,* made with a round orifice the size of which could be easily changed; a superheating coil, *E,* heated by a gas flame for controlling the quality and temperature of the steam, and a threeway valve, *F,* for turning the steam quickly from the main steam jet, *D,* to a similar jet, *H,* to secure a practically continuous and steady flow of steam through the superheater, *E,* so that its temperature and quality characteristics might be better controlled. The jet, *H,* carried off the waste steam. The housing, *I,* surrounded the can. Thermocouple points, *J,* were soldered to the can and connected to the millivoltmeter, *V,* and to a cold junction, kept at 32° F. A steam gauge, *M,* and thermometers *L,* and *O* completed the arrangement.

The general method of procedure during the tests was to place a can in position above the jet, turn on the steam to warm it, then turn off the steam and turn on the cold water to bring the temperature down to normal. This cycle was repeated several times until the readings became constant, after which the test proper was made.

Readings of the millivoltmeter were taken at intervals of five and ten seconds for periods of one minute. There was some lag in the movement of the needle, but it was negligibly small, as the heat capacity of the thermocouples was small. After some practice readings

could be taken accurately, and different tests checked closely. All readings were taken three or more times. The thermocouples were moved so that the temperatures of different positions on the can were measured.

Effect of Steam Pressure on Rate of Heating.—Figure 9 shows graphically typical curves obtained with saturated steam on the 0.25-inch nozzle, when the pressure was 20, 40, and 60 pounds. The rate of heating was markedly slow when only 20 pounds pressure was used, while there was not much difference in the rate between 40 and 60 pounds pressure. Evidently, then, with the 20-pound pressure,

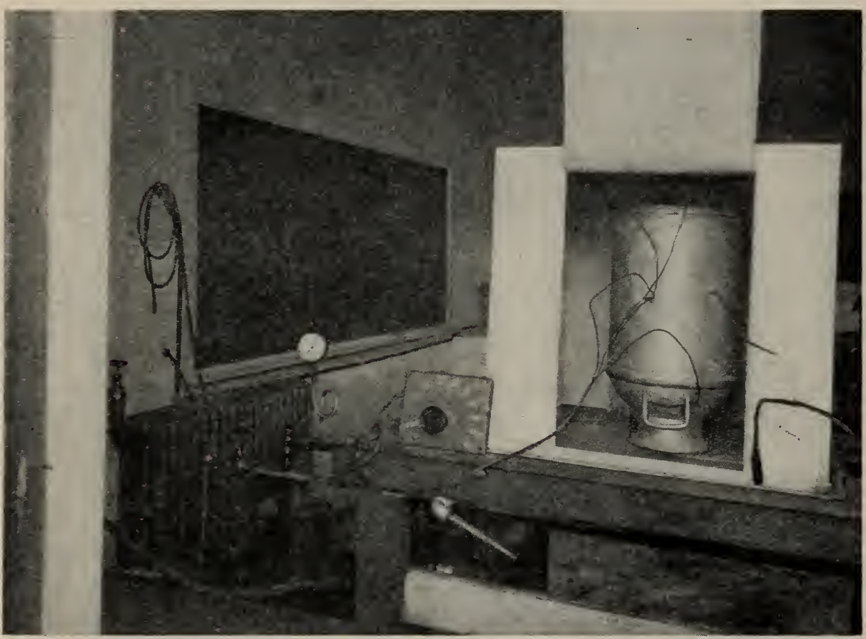

Fig. 8.—Apparatus used to test rate and uniformity of heating of milk cans.

steam was not admitted fast enough to maintain the saturation temperature of the steam within the can during the first 40 seconds; while with both the 40- and 60-pound pressures, the temperature was practically maintained after the first 20 seconds. It shows that equilibrium in all cases was finally reached at a point of approximately constant temperature.

These data are of practical significance because they emphasize the necessity for a large momentary volume of steam at the jet to bring the can temperature quickly to the proper point, and because

they show that this volume could be decreased markedly in the interests of economy after attaining the proper temperature. A valve operated by a cam in such a way that it comes to 'full open' quickly and then closes gradually would appear desirable. It is only a waste of steam to allow a heavy flow to continue after the can has been brought to the proper temperature.

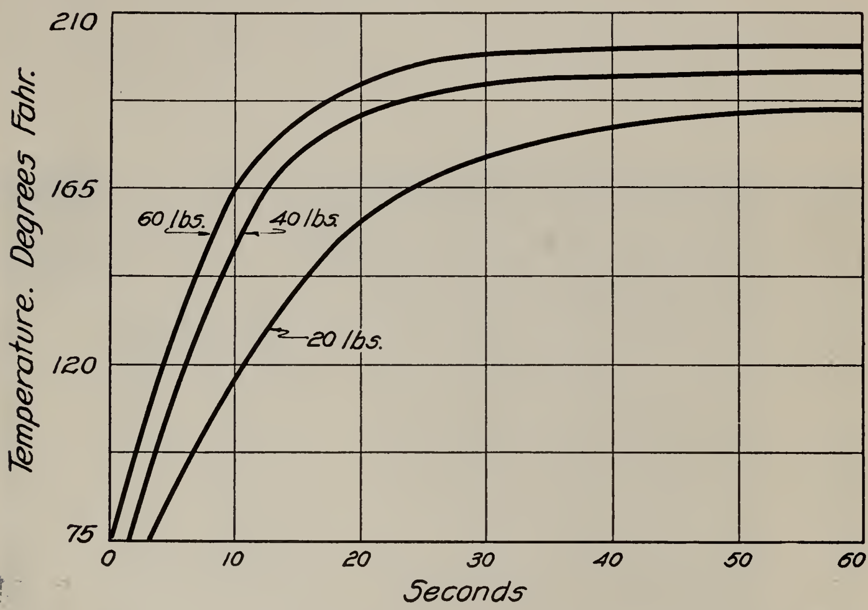

Fig. 9.—The effect of various steam pressures on the rate of heating of the can metal. Size of steam jet orifice was 0.25 inch.

Effect of Quality of Steam on Rate of Heating.—Figure 10 shows data obtained when the quality of steam was varied from wet to dry superheated, keeping all other factors constant. Steam pressure was 40 pounds, and the orifice was 0.25-inch. The rate of warming of the can was very nearly constant for all kinds of steam during the first fifteen seconds, although the very high-temperature superheated steam showed somewhat more rapid heating during the first thirteen seconds. These data clearly show that wet or saturated steam heats more readily per degree temperature difference between it and the can than does superheated steam; the latter will, however, give a higher final temperature if it is maintained long enough. The transmission of heat from wet steam to metal is better than from superheated steam to metal.

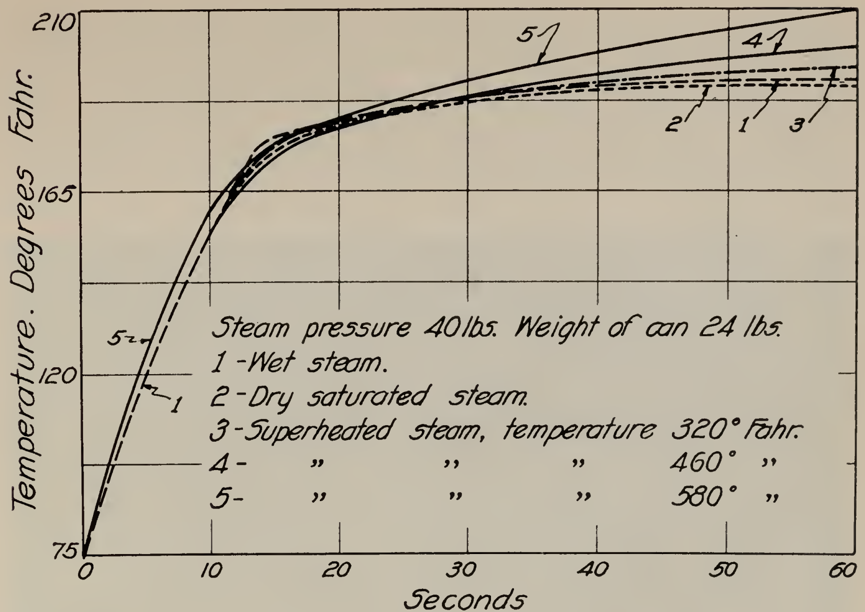

Fig. 10.—Curves showing the rate at which a ten-gallon milk can was heated over jets of steam similar except for quality. Note that the high-temperature superheated steam does not heat the can much more rapidly at first than does the wet and saturated steam, but that the final temperature is higher.

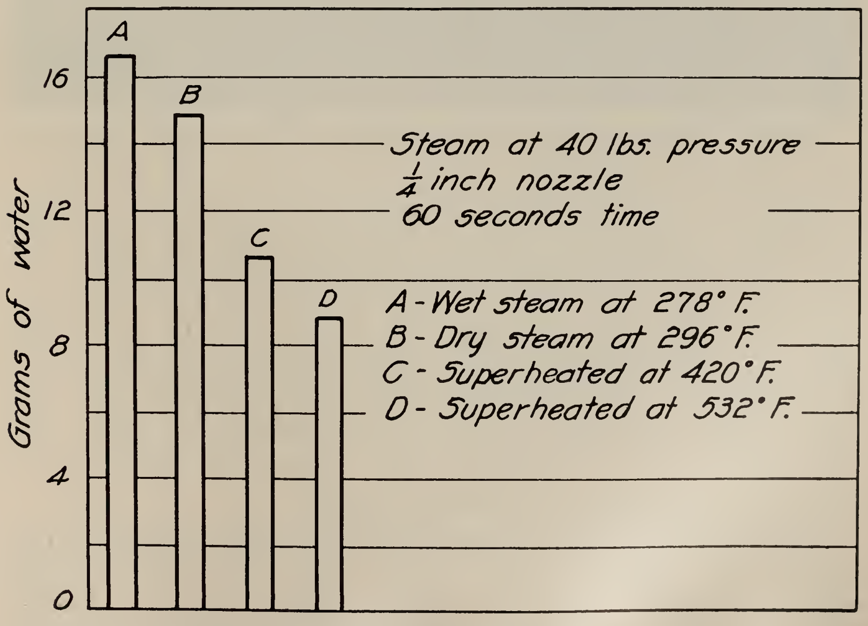

Fig. 11.—Amount of moisture in grams, which remained in 10-gallon milk cans after exposure for one minute over steam jets using wet, saturated, and superheated steam respectively.

Effect of Quality of Steam Upon Amount of Moisture Left in Cans After Steaming.—Superheated steam has the power of absorbing moisture (see fig. 6), from the surface of the can, or at least preventing an excessive amount of moisture from remaining in the can after steaming. This has been proved in laboratory tests and in actual practice.

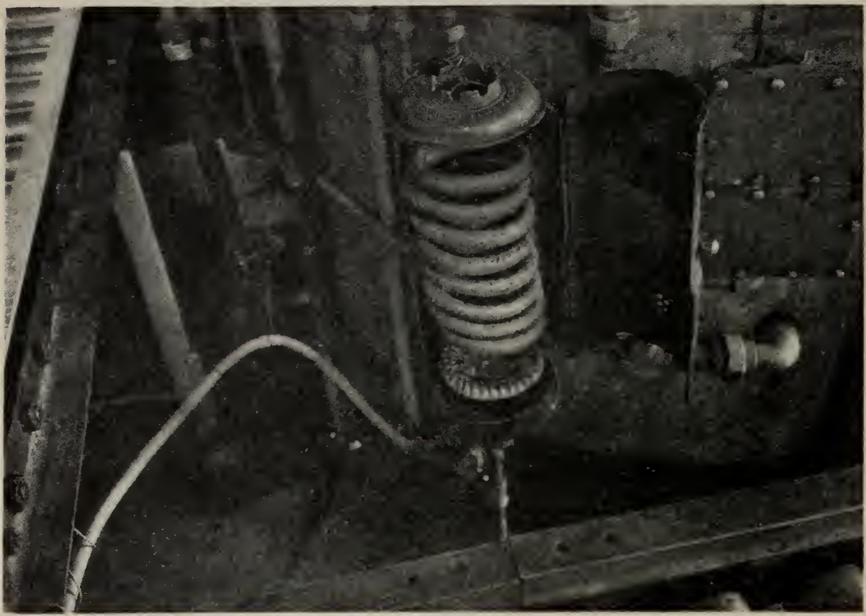

Fig. 12.—Gas-heated experimental superheater which supplied superheated steam to the last steam jet on the can washer. Housing opened for photograph.

Figure 11 gives the results of laboratory tests to show moisture remaining in a single can after it has been steamed for 60 seconds with the various qualities of steam indicated. With wet and dry saturated steam, the water was 16.50 and 14.95 grams respectively, while with superheated steam this amount was cut down to 10.42 and 8.35 grams per can, depending upon the temperature. Obviously, then if superheated steam is used in the last steam jet of a can washer, the drying process is materially aided, because less moisture is left to be removed by the air-drying apparatus.

A practical test of the value of superheated steam was made by attaching a gas-heated superheater figure 12 to a can washer operating under commercial conditions. During the use of the superheater which furnished superheated steam for the last steam jet, the cans usually came out with a dull, dry appearance and very seldom with

any visible moisture present. Table 4 shows the moisture remaining in cans after passage through the washer, using various qualities of steam. Considerable improvement was noted in the efficiency of drying small one, two, and three-gallon cans when the superheater was used. On the washer studied, the regular air-dryer nozzle was so large that it practically covered the mouth of the cans and prevented free circulation of air up into the can. The small high-pressure jet of superheated steam easily entered the can, however, and carried out most of the water. Apparently, then more positive drying could be obtained if the drying air was forced in under relatively high pressure and forced through a smaller jet to give it sufficient velocity to travel to the top of the can and thus more thoroughly reach all parts of the metal.

TABLE 4

Moisture Retained in 10-Gallon Cans After Passage Through Washer

Can No.	Condition of steam used in jet	Temp. of solution	Weight		Condition of	
			Calcium chloride	Water	Can	Lid
		°F	*grams*	*grams*		
1	Wet	160	111.4	1.3	Smooth	Smooth—tight
2	Wet	160	122.8	0.6	Smooth	Very smooth—tight
3	Wet	160	132.8	1.3	Smooth	Smooth—tight
4	Wet	165	127.6	1.3	Smooth	Smooth—tight
5	Wet	165	126.9	1.6	Smooth	Rough—loose
6	Superheated	170	129.4	0.9	Smooth	Some rust—slightly loose
7	Superheated	170	131.9	0.8	Smooth	Smooth—tight
8	Superheated	170	124.5	0.7	Smooth	Smooth—tight

Average: Moisture retained in good cans and lids—wet steam treatment—see cans 1, 3, and 4 = 1.3 gram
Moisture retained in good cans and lids—using superheated steam—see cans 6, 7, and 8 = 0.8 gram
Moisture retained in good can with very smooth lid—see can 2 = 0.6 gram
Moisture retained in good can with rough lid—see can 5 = 1.6 gram

Note.—Cans and lids were taken from machine, and lids applied immediately. Moisture was absorbed by flake calcium chloride in open shallow, glass containers set in the bottom of the cans for 18 hours. No free water was visible in the cans, either before or after moisture was absorbed by the calcium chloride.

Uniformity of Heating of the Can Over Steam Jets.—With the special apparatus, tests were conducted to measure the uniformity of heating of the can metal. Points were established, as shown in figure 13, for the location of the thermocouples as listed. All were soldered to the outside of the can metal except Nos. 6 and 7 which were carried through a small hole and soldered to the inside of the

can, at the same time closing the hole. In view of the relatively high conductivity of the can metal the difference in rate of heating would probably not be appreciable with the type of jet used, for the steam was distributed thoroughly and no one place received a strong current of steam as if a concentrating type jet were used. Figure 13 also shows the results obtained. It is evident that the difference in the rate of

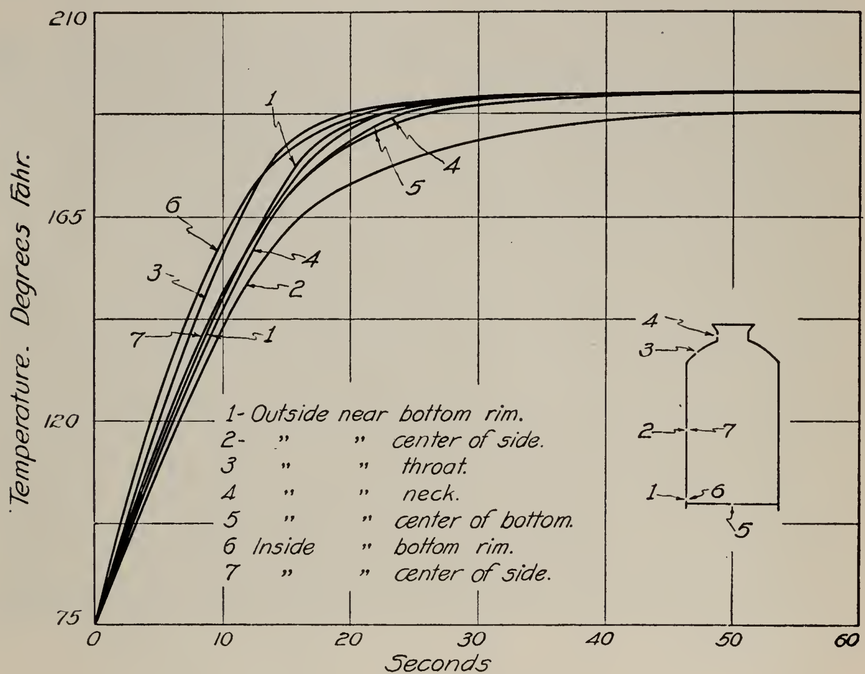

Fig. 13.—Location of thermocouples used in testing uniformity of heating of milk cans, also temperature of various parts of a can when heated over a steam jet. Size of orifice, 0.25 inch; steam pressure, 40 pounds.

heating is not great, but that the most rapidly heating part is in the corner near the junction of the can bottom and side. This conclusion seems natural because it is here that the condensate which is practically as hot as the steam, will tend to collect during the steaming process, and due to its greater conductivity, will maintain a higher temperature, than where steam alone impignes. Position 3 also heats rapidly, no doubt due to condensate dripping down and also to the high velocity of escaping steam as it passes this point. Position 2 heated least rapidly, evidently because radiation from this part of the can is marked, and also because it is a point where cold air may strike if it should be drawn in with the steam. The temperature variation of the can metal amounted to 14.6° F at the end of a 15-second

steaming period, but only 5.7° F after a 30-second period. Further experiments are needed to measure these temperatures when other types of jets are used.

From the foregoing, it appears desirable that the first steaming of the can should be done by wet steam, this to be followed by dry saturated steam or, preferably, superheated steam.

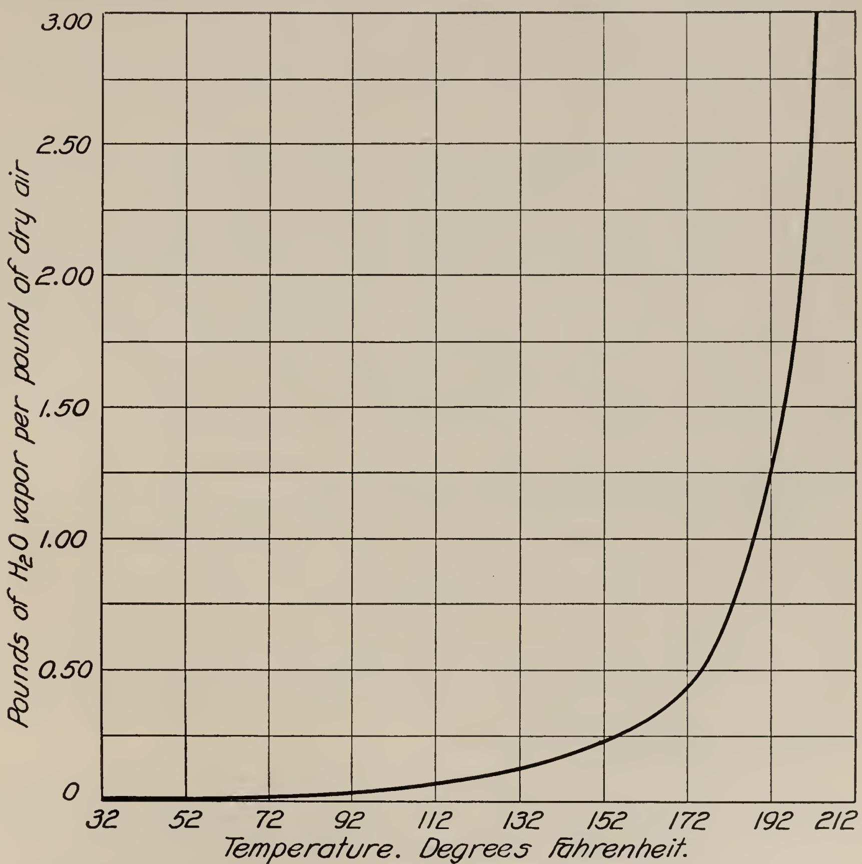

Fig. 14.—The moisture-holding capacity of air at various temperatures. From Kent.

THE DRYING PROCESS

The drying of cans is one of the most important functions of the continuous washer, because the lid is usually placed on the can immediately after it comes from the machine, and there is therefore no further opportunity for removal of moisture. Lack of thorough drying may cause bad odors and high bacteria counts in cans after they have stood for a while. These in turn affect any milk subsequently placed in the container.

The drying operation is usually performed by passing a jet of heated dry air into the can. Moisture in the can is absorbed by this dry, hot air and carried out.

The moisture-holding power of air is largely controlled by its temperature and humidity. The hotter the air, the more moisture it will hold or absorb. Figure 14 shows that at 32° F and at 14.69 pounds absolute pressure, one pound of air holds only 0.00374 pound of moisture; while at 175° F it will hold 0.50 pound. If the curve were extended to 192° F, it would point to 1.25 pounds of moisture per pound of air.

The relative humidity of the air is important, for if this is 100 per cent, the air is saturated and will hold no more moisture; whereas if the relative humidity is 50 per cent, the amount it can absorb will be equal to that already held. In most washers, the air is heated by means of a steam coil and blown up into the can through jets from 2 to 3 inches in diameter. Temperatures attained at the nozzle have been found to be from 180 to 230° F. Higher temperatures would be desirable, it seems, and could be attained by means of larger heating coils or higher pressure of steam. The steam coil should be fitted with a trap to remove moisture of condensation automatically and as rapidly as it is formed.

Some difficulty has been encountered in getting the air to penetrate to the bottom of the can, especially with small mouthed cans, and rising jets have been tried with a fair degree of success. It seems desirable to use a higher pressure and a smaller nozzle to effect good penetration into the can. The air intake to the blower should of course be located in a place which will allow only clean, relatively dry air to be drawn in.

The final air-drying treatment in one of the latest model washers consists of a cold air jet for the purpose of removing any warm air which may remain in the can. This treatment also aids in cooling the can so that it may be readily handled; this after-cooling eliminates some of the moisture which might otherwise condense from the hot air in the can as cooling took place.

It was found by experiment that the drying process was facilitated if the cans were at a high temperature and relatively free from water at the time they entered the drying compartment. This was shown in a practical way by the improvements in drying noted when high-temperature solutions and superheated steam was used. See table 4; page 19.

Treatment of Lids.—The lids of the cans are perhaps more difficult to wash and dry than the cans themselves, because of the nature of the irregular surfaces. They are usually given the same treatments accorded the cans. Frequently the bead on the rim of the can lid will hold a considerable amount of water, which drops into the can when the two are removed from the machine. Figure 15 shows a type of lid which collects less moisture and will come from the machine dry in any ordinary position. It has the disadvantage of any plug-type lid, namely, that water may collect inside through a leak and rust holes through it, but the absence of water-holding cavities on the outside makes it worth considering. Table 5 shows the amount of moisture left on different types of lids tested in a rotary machine; it also indicates the amount of moisture which was found to collect around the bead of the can lip. Note that making the bead flush with solder decreased the amount of water retained per can from 1.49 grams to 0.375 gram.

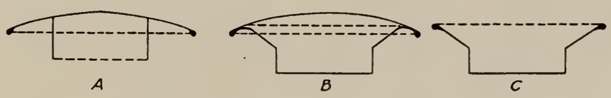

Fig. 15.—Cross-section diagram of three types of milk-can lids used in experiments. Note that type *B* has no surfaces which retain moisture. Type *B* lid was constructed by combining the top of a type *A* with a type *C*. All seams and joints were flushed with solder.

TABLE 5

MOISTURE IN GRAMS RETAINED BY VARIOUS TYPES OF LIDS AND CAN LIP BEADS AFTER PASSING THROUGH A CONTINUOUS CAN WASHER

	Grams of water retained per can or lid	Number of trials
Sanitary 1-piece lid, type C	9.5000	30
Mushroom lid, type A	1.1330	20
Combination lid, type B	0.0907	7
Regular can lip bead (10-gallon can)	1.4910	10
Regular can with lip bead filled flush with solder (10-gallon can)	0.3750	10

Splashing of Moisture.—Many machines are so made that water splashed from jets, tops of cans, can beads, or lids falls into the cans, thus preventing a good job of drying. This is a serious defect and should be remedied. It may be worth while to build the drying compartment separate from the washing and steaming part of the washer.[3]

[3] See description of types of washer, page 4.

It is well known that *most of the moisture will evaporate from the surface of a hot can if it is left standing upright for a few minutes with the lid off.* Actual tests of a series of cans showed 2.15 grams of moisture remaining per can when the lids were applied immediately after their removal from a washer, but that this was reduced to 1.96 grams when the lids were left off for 1½ minutes before their application. Some operators let open cans run out onto a roller conveyor with the lids attached by means of a chain, and then periodically replace a series of covers after allowing time for the cans to dry out. Some operators who unload the washed cans and lids by hand have acquired the habit of shaking the moisture off the lid of the can in such a manner as to prevent it from falling into the can. These practices are good.

POWER CONSUMED BY WASHERS

Most can washers use power or energy supplied by one or all of the following: steam, water, and electricity. The steam is used for heating the solutions, and steaming through jets may also be used for operating a steam pump for circulating solutions, and for driving the air-drying apparatus.

Water is used primarily for rinsing cans and replenishing the supply of liquid in the solution tanks to take the place of that lost in the overflow.

Electric power is used to circulate the solution and the air for drying.

The energy used by a washer is of considerable economic importance, as shown by table 6, which gives results of tests conducted on a number of different makes of can washers.

The *steam requirements* of the washers, as shown in the table, while not strictly comparable on account of differences in capacity, yet show several important points. First, types *A* and *D*, which used steam-driven pumps, were highest in total steam consumption, requiring 66 and 72.75 boiler hp. respectively. The steam required per can was also high, being 5.446 and 4.58 pounds. Washer *E*, which used 'steam guns' for circulating the solution, was also high in steam consumption, as will be noted. Washers *B*, *C*, and *F* all used motor-driven pumps and consumed only 1.84, 2.17 and 3.64 pounds of steam per can respectively. It should be noted that type *F* washer used continuous jets which remained on at all times. It was an old-fashioned machine. The other machines were all of the intermittent jet type.

The *water* consumed by the washers varied from 0.85 to 4.07 gallons per can washed. Type A used a large amount of water for cooling the wash solution (which was heated by exhaust steam from the pump). This precaution was necessary in order to make the pump work, for the supply of heat from the exhaust steam was so great as to heat the solution almost to the boiling point, thus preventing it from being drawn into the pump. A device to bypass a part of the exhaust steam would perhaps overcome this difficulty. Type *E* used a larger amount of water because of the practice of supplying fresh water each time to several of the large jets.

TABLE 6

TABLE SHOWING STEAM, WATER, AND ELECTRICITY CONSUMED BY VARIOUS CAN WASHERS USED UNDER COMMERCIAL CONDITIONS

Type washer	Cans per hour, capacity	Cans per hour (actual)	Pounds of steam per can	Boiler hp. to operate	Water used per can, gallons	Kw.-hr. per 100 cans
A	360	360	5.44	66.00	3.61	0.271
B	385	385	1.84	23.60	0.85	0.924
B[1]	385	140	5.19	24.20	0.85	1.480
C	240	240	2.17	17.45	1.93	0.843
D	600	495	4.58	72.75	2.72	0.045
E	300	264	5.59	47.08	4.07	0.079
F	600	403	3.64	43.17	1.08	2.360

Type— *Description of Washers*

A —Rotary, with steam pump and rising intermittent jets.
B —Straight-away, with motor-driven pumps and stationary intermittent steam and water jets, the latter on only when can is in correct position.
B[1] —Same as *B*.
C —Rotary, with motor-driven pumps and stationary intermittent jets.
D —Straight-away, with steam pump, and rising intermittent steam jets.
E —Straight-away, with steam-driven pumps, and intermittent jets.
F —Straight-away, with motor-driven pump and continuous steam jets.

The *electricity* consumed varied from 0.079 Kw-hr. to 2.36 Kw-hr. per 100 cans washed. The types using steam-driven pumps required negligible amounts of electrical power, for operation of the carrier, which was the only part electrically driven.

Operation at partial load greatly *increases* the *cost* of *per can,* as will be noted in a comparison of types B and B[1] (table 8), the latter of which gives results obtained with type "B" washer under slightly less than half load. The average steam consumed per can was increased from 1.84 to 5.19 pounds per can; the water was not increased, but the electricity was increased from 0.924 to 1.48 Kw-hr. per 100 cans. These figures were obtained from a washer which had automatically opening valves on the steam and water jets. Those on

the steam jets opened for a certain length of time, regardless of the presence of a can; while the water jets opened only when a can was present. The increased cost of operation per can is due largely to the fact that in this type of washer the heat losses go on just the same when running empty as when at full load. The automatic water valve which opened only when a can was in position saved practically all waste of water.

TABLE 7

STEAM REQUIREMENTS OF VARIOUS PARTS OF A WASHER WITH A CAPACITY OF 240 CANS PER HOUR, USING MOTOR-DRIVEN PUMPS AND INTERMITTENT JETS

Part of washer	Steam flow in pounds per hour
Sterilizing nozzle	102.84
Air heater	73.80
Steam jet (for blowing water from bottom of cans)	61.43
Sterile rinse	184.60
Heat water	110.97
Total	523.64

The distribution of steam required to operate a type *C* washer is shown in table 7. This is of interest because it shows where savings might be made by the use of jets which operate only when the can is in position to be steamed. Thus the sterilizing nozzle requiring 102.84 pounds, the steam jet with 61.43 pounds, and the sterile rinse, with 184.6 pounds, controlling 348.87 pounds out of the total of 523.64, might be shut off under such conditions and make a saving in steam. The temperatures of the solutions and air should be maintained by the remaining 174.77 pounds.

TABLE 8

STEAM REQUIREMENTS OF PARTS OF WASHER WITH A CAPACITY OF 360 CANS PER HOUR, USING A STEAM-DRIVEN PUMP AND INTERMITTENT JETS

Part of washer	Steam pressure, pounds per square inch	Flow, pounds per hour	Pounds of steam per can
Steam pump	78.08	711.8	2.370
Steam jets and air heater	79.00	790.8	2.636
Total flow		1,502.6	5.006

Table 8, showing the steam requirements of a type *A* machine, illustrates the fact that the steam pump requires almost as much steam as the jets and air heater combined. In this washer, the exhaust steam was used to heat the wash solution. The difficulties encountered were: first, the solution became so hot it would not pump properly; and, second, oil from the pump was carried over into the wash tank and caused an objectionable deposit on all cans washed in the machine.

CARE AND OPERATION OF WASHERS

The care of a washer consists of rigid cleanliness, proper adjustment, and periodic inspection. The following points, if attended to regularly, should insure satisfactory operation:

1. Keep the washer clean.
2. Use plenty of high-pressure steam.
3. Keep all jets open and working properly.
4. Keep strainers clean.
5. Keep washing solution at proper strength.
6. See that all automatic opening valves function properly.
7. Take the air through intakes placed in a dry, clean place.
8. Use good thermometers on all important solutions, and be sure that such solutions are at the proper temperatures during the operation of the machine.
9. Keep the machine well painted where possible, and treat all shafts to prevent corrosion.
10. Keep all moving parts well lubricated.

TABLE 9

The Variation in Steam Flow Through a Steam Jet in a Washer Resulting From Poor Adjustment of Operating Triggers

Trigger No.	Pounds steam used per can washed
1	2.871
2	2.133
3	3.155
4	3.155
5	3.155
6	3.155
7	2.043
8	2.243
9	1.849
10	2.640

Note.—Each can, when in position, pressed down a trigger, which opened the steam jet as the can passed over.

Special attention should be given to checking the operation of washers with automatic jets, for they sometimes get out of adjustment. Table 9 shows readings made of the steam flow through the sterilizing nozzle of a can washer, in which the nozzle was turned on by a trigger operated by each can. It is evident that in this case some of the triggers were not operating correctly, for out of the 10 openings only Nos. 3, 4, 5, and 6 gave the full amount of steam. No. 9 gave only 1.849 pounds of steam per can, or 58 per cent of the normal amount. The trouble was caused by poor adjustment of the triggers, which was easily remedied.

SELECTION OF WASHERS

The selection of a can washer necessitates careful analysis of the individual plant requirements to determine:

1. Capacity.
2. Load factor.
3. Quality of drying necessary.
4. Space requirements.
5. Boiler capacity available.
6. Relative cost of steam and electricity.
7. Method of handling cans for most economical results.
8. Man-power available.

The machine should, if possible, be of sufficient capacity to handle all ordinary runs, and yet maintain a high load factor, which is desirable and essential for economy of operation. This result can sometimes be obtained by storing cans until all are ready to wash. Such practice has its disadvantages, however, since it requires extra can-storage space and also makes it impossible for the patron to take away his cleaned can immediately.

The boiler should be large enough to furnish sufficient steam for the washer, in addition to meeting other requirements of the plant. It might be possible to use a washer with motor-driven pumps where an entire steam-driven outfit would be out of the question, since the former requires a relatively small amount of steam. The relative cost of steam and electricity is an economic question which might determine whether the all-steam driven or steam-electric would be best.

The method of handling cans is important, for with some types of washers a continuous transfer system may be used, whereas with other types it is necessary to stack the cans and put them into and remove them from the washer by hand.

The question of man-power and cost of labor is also important, because with some machines only one man is required for dumping, washing, and unloading, as compared with two or three required under other systems.

The washer should be as simple in construction as is consistent with good performance. It should be sturdily built of durable material. Galvanizing of parts is advantageous. Automatic valves and rising jets, if used, should be exceptionally well constructed; otherwise, they can be a source of much trouble. It is important to know that repair parts can be obtained promptly and conveniently.

SUMMARY

1. Clean, dry, sterile cans are of great importance in maintaining a high quality of milk.

2. There is room for improvement in the care and operation of the average can washer in the plant.

3. The proper cycle for can washing appears to be draining, rinsing, washing, steaming, and drying.

4. Efficiency in washing is maintained by keeping all jets and tanks clean, and all solutions at the proper temperature.

5. The can temperature follows the temperature of the jet very closely.

6. Wet or saturated steam is satisfactory for heating cans and giving them the first steam treatment.

7. Dry and preferably superheated steam should follow the wet steam treatment.

8. Attachment of a superheater may improve the drying powers of a can washer.

9. High-pressure steam is desirable for can washers in order to obtain high temperatures.

10. The temperature is practically the same in all parts of the can when it is steamed over a high-pressure jet.

11. Drying of cans requires high-temperature air taken from a dry source.

12. Smooth cans are easily dried and rendered sterile, whereas those containing rough seams are not.

13. There is a real need for a good seamless can.

14. The can lids are difficult to dry and wash; a dome type lid showed good results from the drying standpoint.

15. Moisture is often splashed into dry cans by jets not properly separated from the drying compartment.

16. Hot cans will dry out very well if they are allowed to stand uncovered for a few minutes in an inverted position.

17. The power consumed by washers operated entirely by steam was from 43 to 72 hp. at capacities ranging from 360 to 600 cans per hour.

18. The steam consumed per can by the steam-operated washers ranged from 4.58 to 5.59 pounds.

19. The steam consumed per can by the combination steam and electric washer ranged from 1.84 to 3.64 pounds.

20. The electricity consumed by the washers varied from 0.84 to 2.36 Kw-hr. per hundred cans for those with motor-driven pumps; others required from 0.045 to 0.271 Kw-hr.

21. Water requirements varied from 0.85 to 4.07 gallons per can washed.

22. The power used per can is greatly increased by operating at partial capacity.

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